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Heap Leaching Metallurgical Studies on Several Ontario Gold Ores

by

M.K. Witte

1981

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Heap Leaching Metallurgical Studies

On

Several Ontario Gold Ores

FINAL REPORT

Northern Regional Development
Ministry of Northern Affairs
Northwestern Area Office

1. INTRODUCTION

In October, 1980, Ontario Research Foundation was commissioned by the Ministry of Northern Affairs to investigate the possibility of heap leaching Ontario Gold Ores. With the rising price of precious metals the operation of mining properties containing small tonnages of average grade ore or large tonnages of very low grade ore has been feasible. One low cost method of handling these properties is through the utilization of heap leaching techniques. Currently heap leaching is being utilized extensively in Nevada, Arizona and other Southwestern States as a method of leaching large tonnages of rock very inexpensively. In many cases the heap leach operation accompanies a conventional mill circuit with the average grade ore processed in the mill circuit and the low grade material handled on the heaps.

Heap leaching has been quoted in the past as "as small Miners' golden opportunity", because the technique allows for the recovery of precious metals with a minimum of capital expenditure. Currently in Ontario many potential mining properties exist with small reserves of average to good grades of precious metals. Because of the small tonnages involved it is not economically feasible to construct a conventional processing plant to handle the ore. Heap leaching may prove to be a viable method of handling such properties and thus the feasibility of heap leaching ore from these types of properties was investigated.

Twelve representative samples of ores from several small Ontario properties were received from the Ministry of Northern Affairs for evaluation. The testwork undertaken included a full evaluation of the leachability of the ores by heap leach cyanidation. More specifically the testwork consisted of assaying, porosity studies, mineralogical studies, column leaching tests

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and conventional cyanidation studies. The testing methods utilized, results, and recommendations for future testwork are contained in this report.

2. DISCUSSION

2.1 Sampling and Assaying of As-Received Samples

Twelve 15 kg ore samples were received for testing. The samples consisted of minus 4 inch material. Before any work was undertaken representative rock pieces up to 3 inch size were selected from each individual sample for porosity testing. The remainder was jaw crushed to minus 1 inch, a 1 kg sample was riffled and rolls crushed to approximately 10 mesh. From this a 200 gram sample was split, ground to minus 200 mesh in a shatter box and submitted for gold and silver assay. The results of the assays for gold and silver are listed in Table I. All ores assayed gold and silver values which made the ores potential heap leaching candidates.

2.2 Porosity Testing of Representative Samples

For the porosity testing, representative pieces of the 3" rock selected from the sample were cut by a diamond saw to provide a level base for placement of the rock piece in a 1/8 to 1/4 inch deep bath of "Zyglow" penetrating oil. The rock was cut across its schistosity or contacts. After 24 hours, penetration was noted by observation under ultraviolet light. The rock was again cut by diamond saw, perpendicular to its base. The penetration of the "Zyglow" oil into the rock fractures was recorded. A second observation by the same method was made one week after placement of the rock in the solution.

Of the twelve ores tested, five showed good to excellent penetration of the "Zyglow" penetrating liquid. These were the schistose ores. Many of the ores received consisted of massive unweathered quartz which showed no porosity (only very shallow <1/4 inch penetration along fractures or contacts).

Recorded observations on each sample are displayed in Table II.

Based on the observations, the following samples were chosen for further studies:

	Au oz/ton	Ag oz/ton
No. 01	0.040	0.21
No. 04	0.094	trace
No. 05	0.567	0.47
No. 11	0.600	trace
No. 12	0.140	0.16

2.3 Mineralogical Studies on Selected Ores

Before column testing commenced the mineralogy of the five ores selected on the basis of porosity was studied. The studies were completed by Dr. J. J. Lefebvre Research Geologist of UMEX. The report is attached in Appendix I. In summary, in all samples except number 5 no discrete gold or silver minerals were observed. A small grain of native gold was found in number 5. The amount of gold reported in the assays seemed to correlate with the quantity of pyrite occurring in the samples.

2.3.1 Column Leaching Studies on Selected Ores

Leaching columns were constructed from 7.7 cm diameter glass columns 120 cm in height. The bottom of the column was wrapped with 100 mesh screen. The column discharged into a 20 litre bucket. A parastaltic pump was used to transfer solution from the discharge pail to the top of the column. This method allowed for the permanent settling of the slimes in the bottom of the bucket.

The ore was stage crushed to minus 1/2 inch and placed in the column to a height of 100 cm. After the first solution was passed through the column some settling (about 10 cm) in the column took place. The duration of the test-work was 75 days (1,800 hours). During this time the solution was pumped 18.5

days (444 hours). The remainder of the time the columns were left draining so that a maximum amount of air could be drawn into the column. The ore in the columns was never allowed to dry.

The solution flow was monitored after a steady flow was established. No carbon adsorption technology was utilized and the solution was simply recycled back to the column. During the test run the solutions were replaced twice to eliminate any possibility of gold precipitation. Solution strength was 0.1% NaCN and 0.1% $Ca(OH)_2$. Due to extreme discoloration of the pregnant solution, cyanide consumption could not be measured. Total sodium-cyanide added during the test run was from 1.3 to 1.5 kg/mt. Lime was added in the same amount as cyanide protection and safety measure. The pH of the solution remained at +10.5.

The results of column leaching and test conditions are shown in Tables 3 - 1 to 3 - 5. Flowrates listed are maximum obtainable, as the leaches were run to simulate ponding conditions in which a solution level is maintained on top of the ore. Gold recoveries calculated on both residue and solution assays are listed. Silver recoveries were calculated on residue assays only.

Solutions were recovered after 3 weeks, 7 weeks and 11.5 weeks. Gold recovery based on solution analysis was calculated from the volume of solution and Atomic Absorpiton (AA) assay. Final solution volume includes moisture content of column. Leachability curves utilizing this data are displayed in Figures 1.1 to 1.5.

Samples of three of the ores were cyanided at minus 200 mesh at 0.1% NaCN concentration in a standard agitated leach test. This served as a cross check on the leachability of the ores by conventional cyanidation. A gold recovery was obtained for three ores under optimized conditions.

Because of limited quantities of ore all of the ore received from #11 and # 12 was needed for the column and thus bench scale leaching tests

were not completed on these two samples. Results from this testwork are shown in Table IV.

After the heap leaching studies were completed the column residues were dried and split. A 200 g sample was obtained from each tailing. A conventional cyanidation test was completed on each residue to determine if additional gold would extract with finer grinding. The results of this testwork are shown in Table V.

3. RESULTS AND CONCLUSIONS

In general the column results on all samples except number 4 were very encouraging. Erratic assays are always a problem when conducting heap leaching studies as a sample of the -1/2 inch material must be carefully split from a large bulk sample. Because heap leach solutions normally carry a large quantity of slimes special care must be taken when performing analysis by Atomic Absorption. Agreement of 10 - 15% on a mass balance with solutions and residues is considered very good.

The following are the detailed results from each ore sample which underwent extensive testing.

Sample 1

Assay and porosity testing of this ore sample indicated that the ore was an extremely good candidate for heap leaching. Head assays on the material were 0.040 oz/ton Au and 0.21 g/ton Ag. Percolation rates through the column containing the Band ore were extremely high at 6053 $L/M^2/hr$. Fines from the column washed through immediately allowing for a clear solution for the bulk of the testing. Maximum gold extraction by conventional cyanidation appears to be around 80% (bulk leach on -200 mesh head material indicated 78%, but further leaching of the column residue indicates a maximum recovery in the high 80's).

Column results indicated a recovery of between 75-80% gold and over 50% of the silver. Because of the good percolation rates and satisfaction recoveries this ore would be a good choice for further testing in the field.

Sample 4 -

Assays and porosity testing of the ore from Number 4 property indicated that the penetration characteristics of the ore were good. Head assays on the material were 0.094 oz/ton Au and trace silver. Percolation rates through the column were adequate but a tremendous amount of slimes were produced. The percolation rate remained constant during the testwork. Recovery from a fine grinding -200 mesh conventional leach test indicated that the maximum recovery of gold was in the range of 40%. Confirmation of this was demonstrated on the column leach with a maximum extraction of 22% obtained. Further leaching of the residue indicated no additional gold recovery. The poor recovery in all cases (both column and conventional leaching) appears to stem from the presence of gold locked with the pyrite and arsenopyrite. Percolation problems may result from the presence of large quantities of dolomite. Overall results on this sample were not encouraging and no further testwork is recommended.

Sample 5

Sample 5 was the most difficult sample to test because the mineralization was not uniform. Because of the presence of native gold the testwork could not be adequately balanced.

The head assay on the ore was 0.5 - 0.8 oz/ton Au and 0.47 oz/ton Ag. Several samples were taken and assayed in an attempt to indicate an average. Bench scale leaching on -200 mesh material indicated an excellent recovery (over 95% Au and 80% Ag). Percolation through the column was good, 1425 $L/M^2/hr$, and the generation of slimes from the ore was not evident. Test

results from the column testing were difficult to evaluate because duplicate assays on the solids could not be obtained. The leach solution contained 25.6 ppm of Au which is an extremely high value. Thus the gold was being extracted readily by the heap leaching technique. It is suspected that a gold extraction of 85 - 90% could be obtained by heap leaching technique on this ore . Eighty-five percent extraction on this material however would leave a tailing of approximately 0.075 oz/ton Au. This tailing would be higher grade than much of the head material currently being heap leached today. Because the gold in this ore is so readily extractable, and the head assay so high it is an ideal situation for a conventional leach circuit. If a conventional leach circuit is not possible heap leaching with a longer than normal residence time on the pads may help produce a low tailing.

No. 11

Assay and porosity testing on No. 11 indicated an excellent potential for heap leaching. The head material assayed 0.60 oz/ton Au. The percolation rate in the column was slow but it did not present testing problems. The solution was full of slimes indicating a generation of fines during the crushing step. The material appeared to "disintegrate" in the column but this phenomena did not affect the percolation rate only the clarity of the solution.

Gold recovery from the column testing was excellent, over 90%. The solids and solution do not balance well and it is felt that the dirty solutions contributed to poor solution analytical results. Further cyanidation of the column tailing indicated an additional 88% extraction of the gold left in the tailing for an overall recovery of over 95%. This ore is an excellent choice for further heap leach studies.

No. 12

Assay and porosity testing on No. 12 produced good results with the head material running 0.140 oz/ton Au and 0.16 oz/ton Ag.

Percolation rates through the column were slow (678 $L/M^2/hr$). This is attributed to the large quantity of iron hydroxide present in the ore.

The ore column leached satisfactorily with over 95% Au extraction from the column leach. Solution assays seemed to be erratic and it is attributed to a dirty solution. Silver recovery was greater than 90%. The tailings for the column leach were ground and releached by conventional techniques. Essentially all additional gold was extracted producing a recovery over 98%. No problems were experienced with the No.12sample and it would make an excellent candidate for further testwork.

In summary all samples except for number 4 leached very well in the column testing. No problems were experienced during the testing in those samples which did not contain free gold. All samples except 4 appeared to have a very good rate of extraction. For scale up purposes it can be estimated that approximately 90 days or less of heap leaching should be adequate for good extractions.

4. RECOMMENDATIONS FOR FUTURE WORK

The heap leaching testwork to date on the five ore samples selected produced results which were very encouraging. All ore samples except number four produced recoveries which were acceptable for potential heap leaching projects. Based on these results it is recommended that further work to study the feasibility of heap leaching be undertaken. Possibilities for future work include the following:

A. A large (12" diameter) column test in the laboratory which would include carbon adsorbtion, stripping, and electrolitic recovery of the gold.

B. A larger scale 5' diameter column test in the field which would experience actual weather conditions. This would allow for the monitoring of environmental parameters.

C. A test heap of 300 - 400 tons to be constructed at the site. Adsorption and stripping columns must also be included for this testwork. This route would allow for the monitoring of all process and environmental parameters.

Because the laboratory testing results were very encouraging it is recommended by the writer that the testwork proceed directly to the field. Caution must be taken however to assure before any further testwork be undertaken that the samples used for laboratory testing are representative of the ore available for field testing.

Metallurgically, heap leaching is a viable method of leaching gold from many types of Ontario gold ores. The problems which must be overcome are physical and environmental in nature. Examples of these problem areas are:

1. Pond design and operation to handle spring run off.
2. Effect of freezing and snow loading on heaps.
3. Effective leaching season.
4. Cyanide build up in ponds in cold weather.
5. Washing procedures to remove cyanide from heaps.
6. Potential oxidation and acid generation from heap leach tailings.

Further testwork in the field will provide information which is needed to examine the total feasibility of the technology.

MK Witte

M. K. Witte
Assistant Director
Department of Metallurgy

MKW:aac

TABLE I

GOLD AND SILVER ASSAYS OF TEST SAMPLES

Sample Property	Au oz/ton	Ag oz/ton
No,1	0.040	0.21
No.2	0.57	1.54
No.3	0.022	0.28
No.4	0.094	trace
No.5	0.567 (0.81)	0.47
No.6	0.042	0.26
No.7	0.078	trace
No.8	0.605	0.31
No.9	0.035	0.32
No.10	0.575	trace
No.11	0.600	trace
No.12	0.140	0.16

(Repeat assay)

TABLE II

POROSITY TESTING OBSERVATIONS

Sample No. 1, showed very good penetration after 24 hours. The ore would be suitable for heap leaching.

Sample No. 2, This non-weathered ore showed only very minor penetration along fractures. It is not suitable for heap leaching.

Sample No. 3, No penetration observed except along minor cracks. Not suitable for leaching.

Sample No. 4 Well penetrated along schistosity after 24 hours. Ore appears soaked after one week. Appears to be suitable for heap leaching.

Sample No. 5, This weathered ore showed good penetration along contacts and fractures. Should be suitable for leaching at -1/2" size.

Sample No. 6, There was only very minor penetration along cracks in the quartz. Not recommended for heap leaching.

Sample 7 Minimal penetration of "Zyglow" along cracks. This ore does not appear to be suitable for leaching.

Sample 8 No penetration observed. Not suitable for heap leaching.

Sample 9 Not penetrated, although the ore appears to be partly weathered. Not recommended for heap leaching.

Sample 10 Minor penetration along quartz-silicate contacts.

Samples 11 and 12 Both samples were well penetrated, especially 12 as it is not only schistose, but also weathered.

TABLE III - 1

COLUMN LEACHING TEST

Sample 1

Test Conditions

Flowrate, per M^2/hr	:	6053 liters
Flow per kg/test feed for test duration	:	978 liters
Moisture retained in ore:		7.3%
Washing replacement of pregnant solution	:	13.2
NaCN, total addition	:	1.45 kg/mt
$Ca(OH)_2$, total addition	:	1.45 kg/mt

Test Results

Weight of test sample	:	12.423 kg	
Head Assay Au oz/t	:	0.04	Ag oz/t : 0.21
Au in test sample, grams:		0.0170	
Residue assay Au oz/t	:	0.01	Ag oz/t : trace
Au in Residue grams	:	0.0043	
Solution Analysis Au ppm:		1.87/7.2 liters	
Au in solution grams	:	0.0137	
Au recovery (from Res. Analysis)	:	75.0%	Ag Recovery: +50%
Au Recovery (from Sol. Analysis)	:	80.6%	

TABLE III- 2

COLUMN LEACHING TEST

Sample 4

Test Conditions

Flowrate, per M^2/hr	:	1184 liters
Flow per kg/test feed for test duration	:	178 liters
Moisture retained in ore:		4.2%
Washing replacement of pregnant solution	:	21.4
NaCN, total addition	:	1.35 kg/mt
$Ca(OH)_2$, total addition	:	1.35 kg/mt

Test Results

Weight of test sample	:	13.377 kg	
Head Assay Au oz/t	:	0.094	Ag oz/t: trace
Au in test sample, grams:		0.0431	
Residue assay Au oz/t	:	0.073	Ag oz/t: trace
Au in Residue grams	:	0.0335	
Solution Analysis Au ppm:		4.66/9.6 liters	
Au in solution grams	:	0.0045	
Au recovery (from Res. Analysis)	:	22.3%	Ag recovery: N.C.
Au Recovery (from Sol. Analysis)	:	10.4%	

TABLE III - 3

COLUMN LEACHING TEST

Sample 5

Test Conditions

Flowrate, per M^2/hr	:	1425 liters
Flow per kg/test feed for test duration	:	236 liters
Moisture retained in ore:		4.2%
Washing replacement of pregnant solution	:	23.6
NaCN, total addition	:	1.48 kg/mt
$Ca(OH)_2$, total addition	:	1.48 kg/mt

Test Results

Weight of test sample	:	12.119 kg	
Head Assay Au oz/t	:	(0.567	Ag oz/t : 0.47
Au in test sample, grams:		0.81)	
Residue assay Au oz/t	:	(0.63	
Au in Residue grams	:	1.33)	Ag oz/t : 0.73 trace
Solution Analysis Au ppm:		25.6/10.5 litres	
Au in solution grams	:	0.2693	
Au recovery (from Res. Analysis)	:	good*	Au Recovery: good*
Au Recovery (from Sol. Analysis)	:	good*	

* Sample No. 5 contains a large quantity of gold as free gold thus it is impossible to obtain a representative assay without crushing several pounds of sample, screening out the free gold and assaying of the fractions separately. Since the total sample attained had to be used for the column test several pounds were not available for this assay technique. No recoveries were calculated but that a good rate of leachability was taking place.

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TABLE III - 4

COLUMN LEACHING TEST

Sample 11

Test Conditions

Flowrate, per M^2/hr	:	811 liters
Flow per kg/test feed for test duration	:	121 liters
Moisture retained in ore:		6.2%
Washing replacement of pregnant solution	:	14.4
NaCN, total addition	:	1.34 kg/mt
$Ca(OH)_2$, total addition	:	1.34 kg/mt

Test Results

Weight of test sample	:	13,481 kg	
Head Assay Au oz/t	:	0.60	Ag oz/t: trace
Au in test sample, grams:		0.2773	
Residue assay Au oz/t	:	0.051	Ag oz/t: trace
Au in Residue grams	:	0.0236	
Solution Analysis Au ppm:		10.59/12.6 liters	
Au in solution grams	:	0.1333	
Au recovery (from Res. Analysis)	:	91.5%	Ag recovery: -
Au Recovery (from Sol. Analysis)	:	48.1%	

Percolation rates slow - dirty solution - possible interference on AA solution analysis, thus solution analysis may not be accurate.

TABLE MI - 5

COLUMN LEACHING TEST

Sample Number 12

Test Conditions

Flowrate, per M^2/hr	:	678 liters
Flow per kg/test feed for test duration	:	114 liters
Moisture retained in ore:		10.7%
Washing replacement of pregnant solution	:	8.3
NaCN, total addition	:	1.34 kg/mt
$Ca(OH)_2$, total addition	:	1.34 kg/mt

Test Results

Weight of test sample	:	13.477 kg	
Head Assay Au oz/t	:	0.14	Ag oz/t : 0.16
Au in test sample, grams:		0.0647	
Residue assay Au oz/t	:	0.004	Ag oz/t : trace
Au in Residue grams	:	0.0018	
Solution Analysis Au ppm:		5.87/9.6 liters	
Au in solution grams	:	0.0521	
Au recovery (from Res. Analysis)	:	97.1%	Ag recovery: >90
Au Recovery (from Sol. Analysis)	:	80.5%	

TABLE IV

CONVENTIONAL CYANIDATION TESTING ON THREE ORES SELECTED FOR HEAP LEACHING

(-200 Mesh Leach Tests)

Sample	1	4	5
Test Duration	48 hrs.	48 hrs.	48 hrs.
Test pulp density	30%	30%	30%
pH before additions	8.5	8.5	8.0
pH after additions	10.7	10.5	10.8
NaCN Consumption	N.A.	5.04 lbs/t	5.24 lbs/t
$Ca(OH)_2$ Consumption	7.0 lbs/t	5.60 lbs/t	5.65 lbs/t
Head Analysis Au oz/t	0.040	0.094	0.567
Residue Analysis Au oz.t	0.009	0.057	0.004
Au Recovery	77.5%	39.4%	99.3
Head Analysis Ag oz/t	0.21	trace	0.47
Residue Analysis Ag oz/t	trace	trace	0.10
Ag Recovery	+50%	-	78.7%

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TABLE V

CYANIDATION TESTS ON HEAP LEACH
COLUMN RESIDUES AT -200 MESH

Sample	1	4	5	11	12
Test Duration - Hrs.	48	48	48	48	48
Test Density %	30	30	30	30	30
pH before additions	7.8	7.9	7.5	7.0	7.7
pH after additions	10.9	10.9	10.8	10.9	10.9
NaCN consumption lbs/t	0.86	1.34	4.34	0.94	0.74
$Ca(OH)_2$ consumption lbs/t	9.0	8.7	7.56	8.0	8.16
Test feed analysis Au oz/t	0.01	0.048	0.51	0.05	0.013
Residue analysis Au oz/t	0.005	0.050	0.006	0.006	0.003
Au recovery %	50.0	nil	98.8	88.0	66.1

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FIGURE 1.1

COLUMN LEACHING SAMPLE 1

Solution Recovery

Time/Weeks	Sol. Volume Liters	Au ppm	Recovery %	Cumulative %
3	3.4	2.56	51.2	51.2
7	1.9	1.49	17.6	68.8
11.5	1.9	1.03	11.8	80.6
Total	7.2	1.87*	80.6	

*calcualted

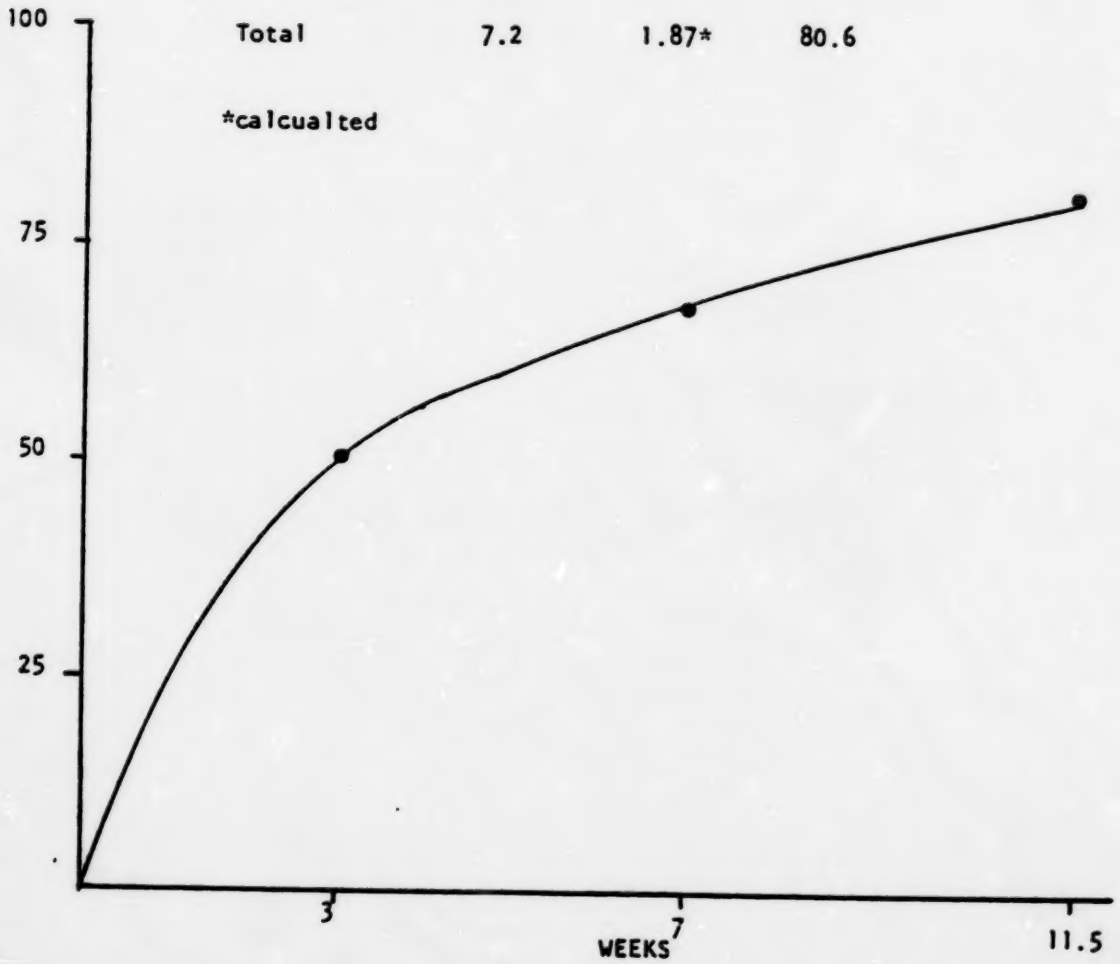


FIGURE 1.2

COLUMN LEACHING SAMPLE 4

Solution Recovery

Time/Weeks	Sol. Volume Liters	Au ppm	Recovery %	Cumulative %
3	3.1	5.80	4.2	4.2
7	3.2	5.90	4.4	8.6
11.5	3.3	2.40	1.8	10.4
Total	9.6	4.66*	10.4	

*calculated

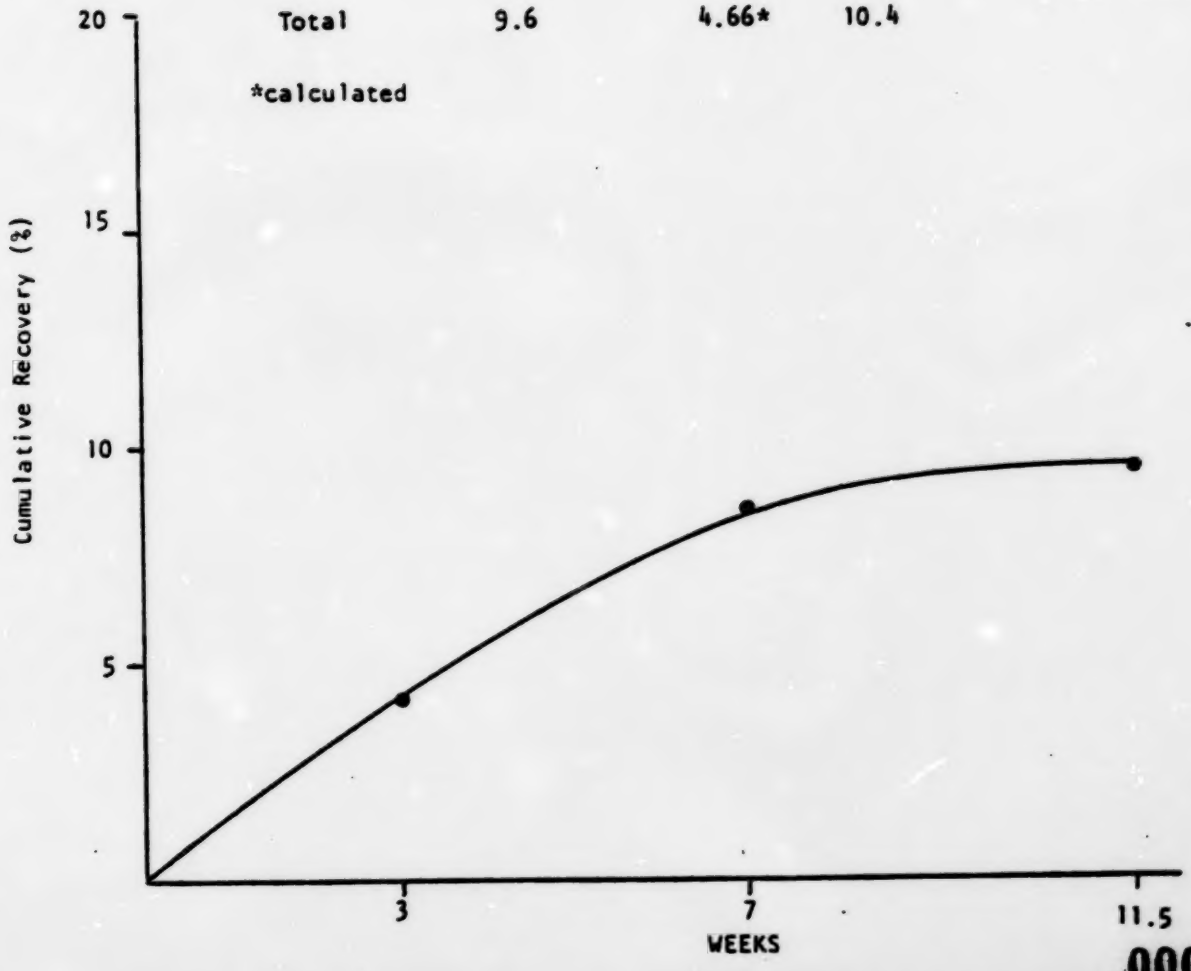


FIGURE 1.3

COLUMN LEACHING SAMPLE 5

Solution Recovery

Time/Weeks	Sol. Volume Liters	Au ppm	Recovery %	Cumulative %
3	3.5	27.5	35.7	35.7
7	3.2	42.1	50.0	85.7
11.5	3.8	10.1	14.3	100.0
Total	10.5	25.6*	100.0	

*calculated

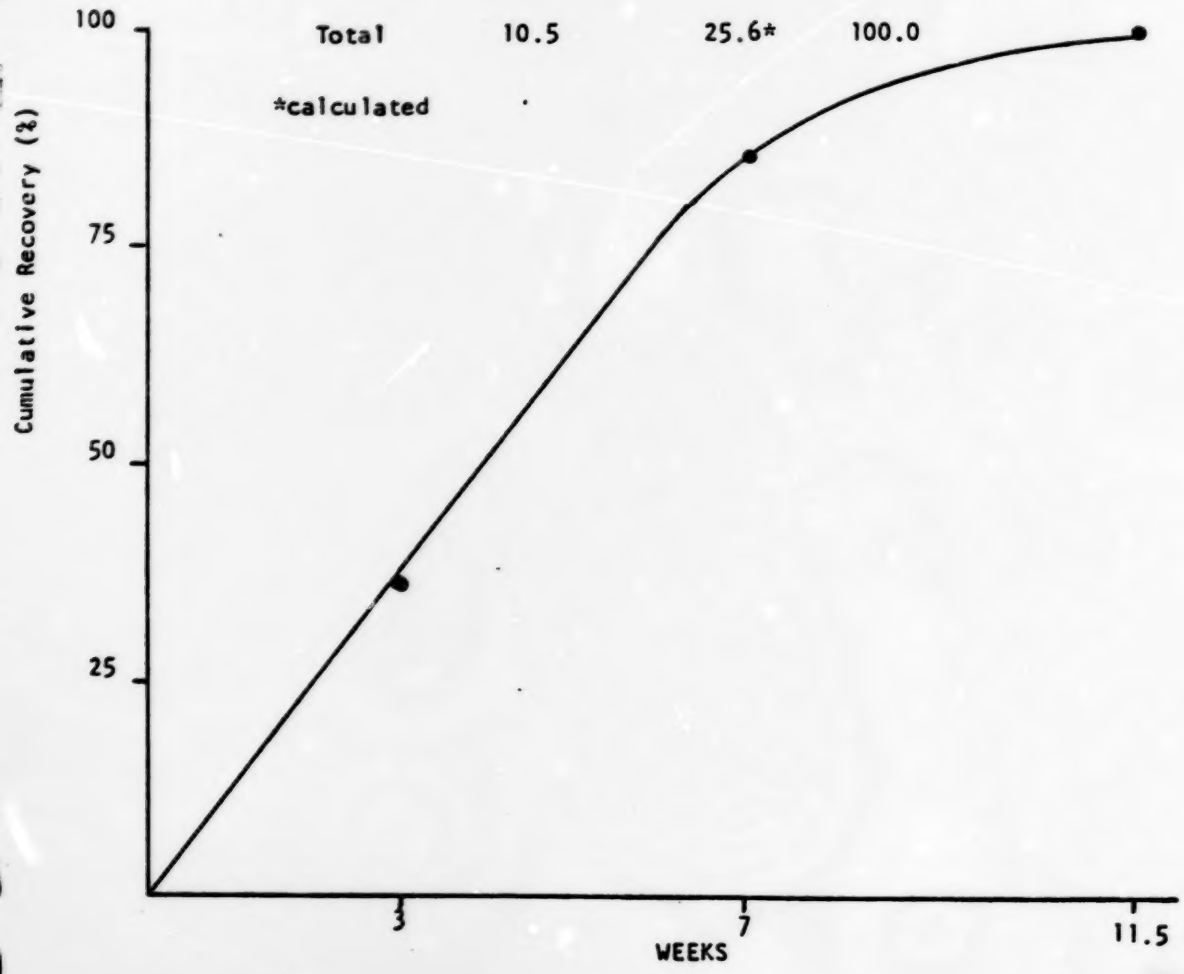


FIGURE 1.4

COLUMN LEACHING SAMPLE 11

Solution Recovery

Time/Weeks	Sol. Volume Liters	Au ppm	Recovery %	Cumulative %
3	5	13.55	24.4	24.4
7	3.8	12.3	16.9	41.3
11.5	3.8	4.95	6.8	48.1
Total	12.6	10.6	48.1	

*calculated

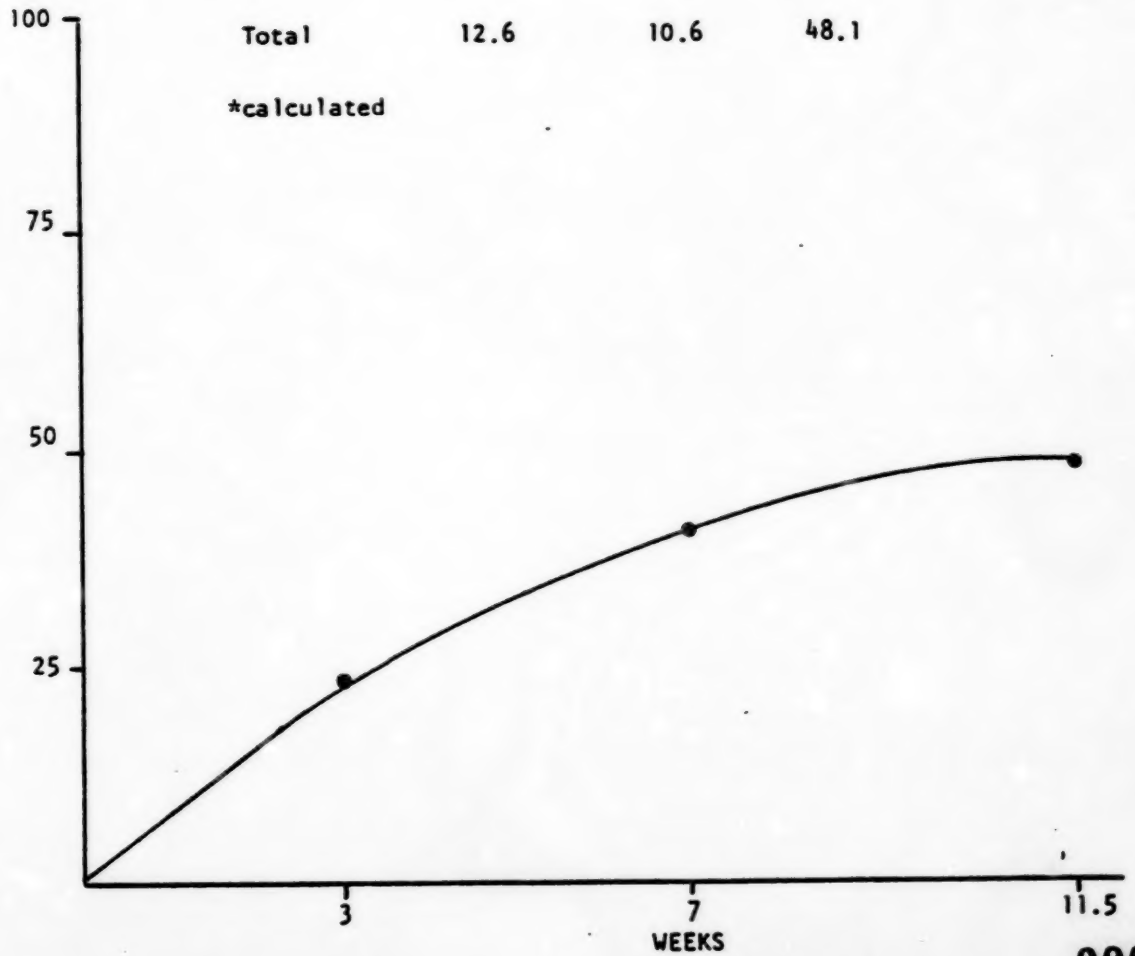


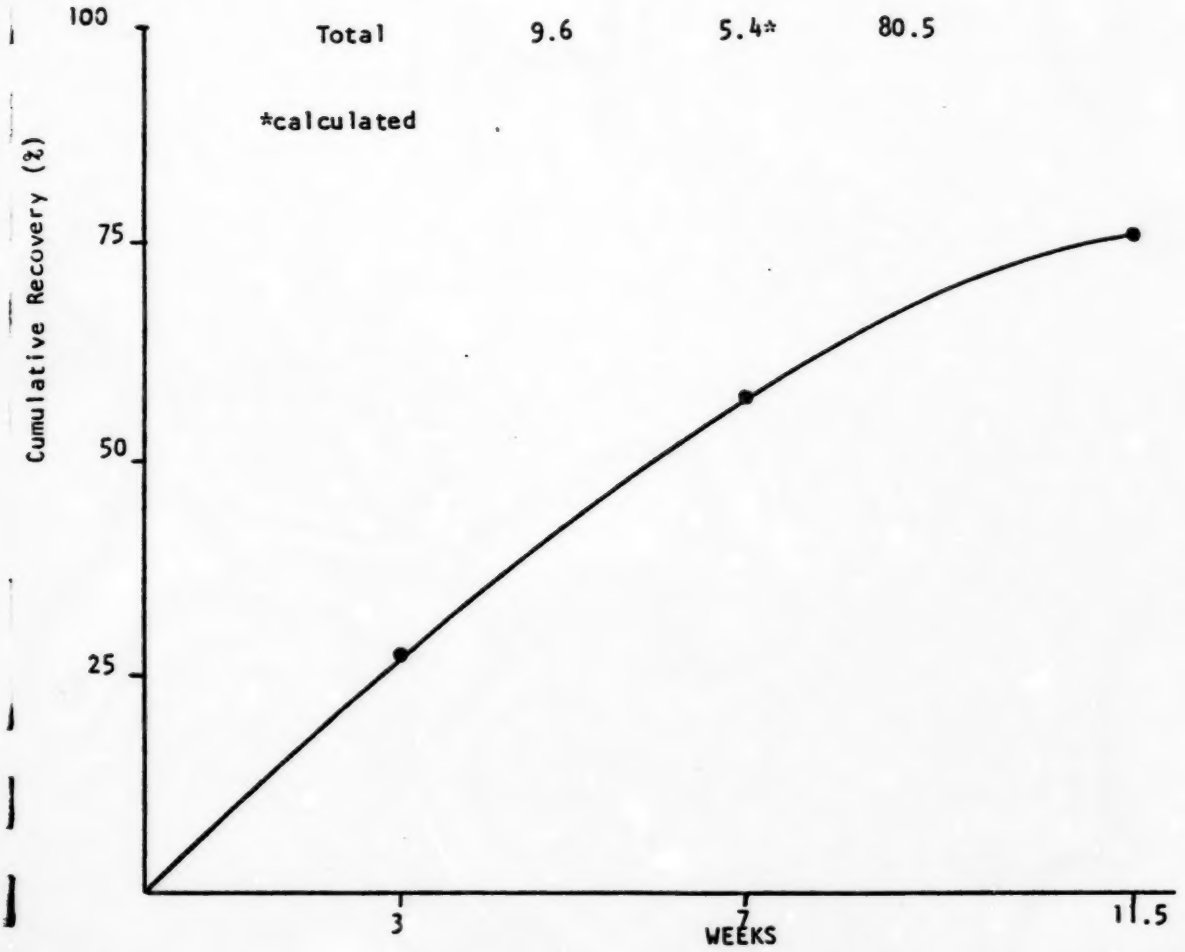
FIGURE 1.5

COLUMN LEACHING SAMPLE 12

Solution Recovery

Time/Weeks	Sol. Volume Liters	Au ppm	Recovery %	Cumulative %
3	2.5	7.0	27.0	27.0
7	2.8	7.8	30.3	57.3
11.5	4.3	3.95	23.2	80.5
Total	9.6	5.4*	80.5	

*calculated



APPENDIX I

LABO 0013

March 11, 1981

PETROGRAPHY, ORE MICROSCOPY, X-RAY DIFFRACTOMETRY AND HEAVY LIQUID SEPARATION APPLIED TO THE STUDY OF FIVE CANADIAN SAMPLES (PO. No. 11129)

J.-J. Lefebvre

Five ore samples were received by the Laboratory from the Ontario Research Foundation for petrographical study in order to determine the rock type and the sulphide mineralogy and to locate the mineralogical phases responsible for the gold and silver content of the ore.

The petrography, mineralogy, size dimensions and distribution were studied using microscopical techniques and point counting. Due to the small size of the rock fragments, only one thin section was prepared (sample 1); for the other samples (samples 1, 5, 11 and 12) the mineralogical content of the gangue was determined using X-ray diffraction techniques. The mineralogical content of F-4 was also confirmed by using X-ray diffraction.

Due to the small quantities of sulphides contained in 2 of the samples, a heavy liquid separation was performed on samples F-1 and 12 in order to obtain an amount of sulphide concentrates sufficient to prepare a polished ore mount.

SAMPLE 1

The material was crushed and the size fraction between 100 and 325 mesh was separated using tetrabromoethane (sp-gr.: 2.95):

floating material	43.05 gr.	97.73% weight
sinking material	1.00 gr.	2.27% weight

The sinking material was used to prepare a polished ore mount and observed using a reflection microscope. Point counting estimation of this concentrate yielded the following percentages:

Free particles

Pyrite	33% weight
Iron oxydes (mostly goethite)	15%
Sphalerite	19%
Chalcopyrite	4%

Locked particles

Sphalerite-chalcopyrite	6% weight
Pyrite-chalcopyrite	3%
Pyrite-sphalerite	2%
Pyrite-iron oxydes	18%
	100% weight

Pyrite is fairly well separated from sphalerite. The size of the chalcopyrite grains is small (mean 45 microns) and most of the grains (60%) are locked with pyrite and sphalerite. No discrete gold or silver minerals were observed.

Polished section study of the uncrushed ore shows a very poor mineralization of chalcopyrite and pyrite (and sphalerite) as finely disseminated grains. Pyrite occurs as poorly sorted, euhedral grains (15 microns to 1 mm), isolated in a rich quartz gangue. Chalcopyrite forms rare aggregates, 10 to 500 microns in size, frequently rimmed by limonite.

The pyrite content of the sample is about 4% and the chalcopyrite content less than 0.5%.

An X-ray diffraction of the gangue material yielded the following mineralogical composition (listed in decreasing order of abundance):

Quartz, mica (muscovite), plagioclase and calcite.

SAMPLE 4

The optical observation of the thin section shows pyrite euhedral occurring discretely and in aggregates, forming approximately 10% of the whole rock. Anhedral quartz crystals are low in abundance and often associated with large dolomite crystals and pyrite. One area appears to be a quartz filled vesicle favouring a possible volcanic origin for the sample. Calcite is very abundant as small subhedral crystals, some showing distinct cleavages. The other primary constituent is muscovite, which occurs in small subhedral crystals in a preferred orientation giving a schistose appearance. The rock type is a pyritized calcareous muscovite schistose rock.

An X-ray diffraction of the sample shows the presence of dolomite in abundance, quartz, muscovite and minor plagioclase.

The study of the polished section indicated the presence of abundant, large, auhedral crystals of arsenopyrite (25%), abundant anhedral crystals of rutile and some euhedral pyrite (5%). There should be no problem of separating pyrite and arsenopyrite from the gangue. The minimum size for total separation of pyrite and arsenopyrite is about 80 microns.

No discrete gold or silver minerals were observed. The only minerals found as tiny inclusions in pyrite and arsenopyrite are rutile and chalcopyrite (5 to 30 microns in size).

SAMPLE -5

The rock material of sample F-5 consists almost essentially of quartz and traces of muscovite (confirmed by X-ray diffractometry).

The sample consists of quartz veins containing chalcopyrite mineralization as rare disseminated aggregates and irregular streaks and stringers. Optical observations of the 2 polished sections, show irregular masses of chalcopyrite with minor inclusions of euhedral limonitized pyrite (20 to 500 microns) and rare formless blebs of sphalerite (80 to 230 microns). Chalcopyrite also contains rare disseminated inclusions of galena (15 to 30 microns and is frequently peripherically replaced by iron hydroxydes. Another primary constituent of this sample is pyrite as large subhedral to euhedral grains (15 microns to 1 mm) disseminated in quartz rich gangue. The pyrite contains locally abundant inclusions of:

sphalerite	(2 to 40 microns)
galena	(7 to 40 microns)
chalcopyrite	(about 50 microns).

A native gold inclusion was observed in only one grain of pyrite, with a size of 21 microns, isolated in the core of the pyrite grain associated with numerous inclusions of sphalerite, galena and chalcopyrite.

Galena is a minor constituent of this sample and occurs as isolated grains (70 to 175 microns) included in iron hydroxyde aggregates or as very rare tiny inclusions (7 to 30 microns) in the quartz grains.

A separation involving a grinding of 60% minus 200 mesh will liberate 70% of the chalcopyrite and 85% of the pyrite from the gangue.

SAMPLE 11

The optical study of the two polished sections prepared from sample 11 yielded the following mineralogical composition:

gangue	58%
pyrite	39%
rutile	3%

Pyrite occurs as large subhedral crystals, 40 to 5000 microns in size with a mean of 1150 microns. Pyrite is loosely disseminated in the matrix or locally concentrated as clusters. More than 80% of the pyritic material would be liberated by a grinding of 60% minus 200 mesh. Pyrite contains rare tiny inclusions of chalcopyrite (5 to 40 microns), extremely rare inclusions of galena (5 microns) and pyrrhotite (12 microns) and possibly rare sphalerite inclusions. No inclusions of native gold were observed, possibly indicating that gold occurs as a solid solution in the pyrite grains.

SAMPLE 11 _ (Cont'd.)

An X-ray diffractometry of the gangue material yielded in decreasing order of importance:

quartz, chlorite and muscovite.

SAMPLE 12

This sample was crushed and the size fraction between 100 and 325 mesh was separated using tetrabromoethane:

floating material	55.11 gram	98.55% weight
sinking material	.81 gram	1.45%

Optical examination of the sinking material on a polished mount yielded the following distribution:

Free particles

pyrite grain and colloidal pyrite	23% weight
iron hydroxyde	36%
pyrrhotite	7%
rutile	27%
magnetite	3%
chalcopyrite	1%
psilomelane (?)	1%

Locked particles

pyrrhotite-chalcopyrite	1%
iron hydroxyde-chalcopyrite and iron hydroxyde-pyrite-chalcopyrite	1%

No discrete gold or silver minerals were observed. The chalcopyrite grains locked with iron-hydroxyde and/or pyrite have a minimum size of 40 microns.

The mineralogical composition of the gangue material determined by X-ray diffractometry indicates the presence of abundant chlorite, quartz and minor calcite.

CONCLUSIONS

With the exception of only one sample (5), where a small grain of native gold was observed included in a pyrite grain, no discrete gold or silver minerals were observed in these samples. However, the amount of gold reported in the assays seem to correlate relatively well with the quantity of pyrite occurring in the samples, suggesting that gold could occur as cryptocrystalline inclusions or as a solid solution in the pyrite phase.

Macroscopical as well as microscopical examination of the samples indicate that the rock samples are probably fine-felsic volcanic material partly foliated and brecciated with abundant quartz-rich lenses and veins suggesting possible faulted ~~zones~~ zones affecting weakly metamorphosed volcanic rocks.

APPENDIX II

SAMPLE DESCRIPTIONS

Sample #1 - 5% - 10% sugary-white quartz vein material. 90-95% sheared and altered meta-volcanic host material. Both quartz vein and sericitized, silicified host material contain minor carbonate and fine sulphides, (< 2%). Sulphides consist of pyrite and minor chalcopyrite. No visible gold noted.

Sample #2 - 85% - 90% quartz vein material varying from milky-white, glassy to smokey black, containing minor carbonate. Quartz material contains up to 60% sulphides (sphalerite, chalcopyrite and pyrite). 10% - 15% altered, sericitized intermediate to felsic metavolcanic. No other gold noted in sample, however, visible gold has been noted in vein material.

Sample #3 - 95% white to smokey quartz material containing less than 1% pyrite and arsenopyrite. Chlorite seams are present in the quartz vein as well as minor carbonate.

Sample #4 - 100% quartz-carbonate-sericite shear zone material. Sample contains approximately 5% arsenopyrite and pyrite. Altered metavolcanic material, silicified, carbonatized and sericitized, makes up approximately 50% of sample. Carbonate is likely ankerite.

Sample #5 - 90% white to smokey glassy quartz material comprised from two separate quartz veins on the property. ½ sample consists of mineralized quartz (≈30% sulphides) containing galena, chalcopyrite and pyrite. Some samples of this vein material contain visible gold. ½ sample consists of barren quartz containing minor carbonate. Quartz veins are hosted by altered carbonatized, sericitized) granite.

Sample #6 - 75% white-milky quartz material, containing minor carbonate seams. Quartz is mineralized with pyrite and arsenopyrite (<5%). Anastomosing quartz veins or quartz stockworks are hosted by altered (carbonatized-sericitized) granitic material (quartz-feldspar-porphyry)≈25%.

Sample #7 - 80% - 85% quartz vein, white and coarse-grained, with scattered chloritic streaks. Occas. carbonate streaks. Less than ½% fine sulphides, largely pyrite with some galena and occas. chalcopyrite. 15% - 20% grey highly altered and sericitized quartz-porphyry wallrock. No visible gold noted, but sample is reportedly free milling and high grade.

Sample #8 - 95% white, fine-grained to cherty looking quartz vein material. Streaky appearance due to streaks of green chlorite-sericite-epidote, reddish-carbonate, and some grey "porphyry" wallrock. 0.5% to 1% fine to medium-grained crystalline pyrite with occas. specks of galena. No visible gold noted.

Sample #9 - Fresh medium-grained quartz, white to rose colored with layered or banded appearance due to staining of the quartz and to streaks of dark minerals, (mostly chlorite). Contains up to 15% sulphides (sphalerite, pyrite, and chalcopyrite in nearly equal amounts). Sulphides mostly occur as coarse (up to 1") splotches.

Sample #10 - Sample consists of pale, felsic (with some sections of darker, intermedium) tuff or quartz-sericite schist. Tuff is mainly cream to white colored, varying from moderately to highly schistose. It is locally very sericitic and contains scattered sections of pervasive silicification which locally appear almost cherty. Only very occasional discrete quartz veins. Slight to moderate carbonate replacement locally. Occasional darker (chloritic) sections of coarser-grained intermediate tuff. Contains < 2% finely disseminated pyrite with occasional narrow-pyrite stringers and concentrations. Visible gold is reported but was not noted.

Sample #11 - Sample consists of highly foliated and schistose sericite-chlorite schist, pale grey to moderate grey in color. Little silicification or quartz vein material. Moderate carbonate throughout. Locally very rusty. Contains 10% to 15% crystalline pyrite.

Sample #12 - Sample consists of highly foliated chlorite schist, (highly sheared mafic-volcanic). Very fissile, crumbly, and earthy with high percentage of fines. Approximately 3% to 5% quartz as very irregular areas and veinlets, occasionally up 1" wide. Minor sulphide.

POOR

QUALITY

ORIGINAL